Air Drying of Cultivated Mushrooms

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SUMMARY

The effects of different processing variables on flavor, color, storage stability, and bacterial population of air-dried mushrooms were investigated. Freshly harvested, firm mushrooms of white variety yielded the lightest products. Increased darkening was apparent with successive breaks dried at the same temperature. Any given break increasing the drying temperature also increased the darkening but the effect of temperature on darkening was less than the effect of break number. Blanching reduced the attractiveness of dry mushrooms; mild sulfiting improved it. Sodium chloride, citric acid and several other chemicals had no effect on color. Chlorine water treatment alone did not provide sufficient reduction in microorganisms. Best results were obtained when mushrooms were washed, dipped in aqueous solutions of chlorine, treated with sulfite to inhibit browning, and dried in two stages, using lower temperatures in the first stage and a higher temperature (170°F) in the shorter finishing stage.

INTRODUCTION

Fresh mushrooms are very perishable. They must be consumed or processed within 4 to 5 days after harvesting. Although hot-air drying is a popular method of preserving wild mushrooms in many foreign countries, air-drying of cultivated *Agaricus bisporus* mushrooms (also referred to as *Agaricus campestris* or *Psalliota campestris*) is limited both in the United States and abroad. According to the United States Tariff Commission (1965) most of the mushrooms grown are canned; only a small quantity of cultivated mushrooms is freeze-dried. The freeze-dried product has very good color and flavor, but is very expensive.

There are several references in the literature to air-drying of cultivated mushrooms. Cruess et al. (1942) and Brunell et al. (1943), for example, give very complete directions for commercial dehydration. Both recommend that mushrooms be blanched to inactivate enzymes and dried at 140°F to 150°F. However, this procedure yields a product unattractive in color as well as shape. McArdle et al. (1962) showed that blanching also results in losses of large amounts of amino acids.

Browning in mushrooms is caused by enzymes which catalyze the oxidation of phenolic substances. Mallette et al. (1949) first reported that the phenoloxidase system present in mushroom tissues consists of several forms, each exhibiting different catalytic and physical properties. Constantinides (1966) separated several enzyme forms. He found the tyrosine specific multiple forms to be little affected by relatively high concentrations of sulfur dioxide but readily inactivated by EDTA (ethylenediaminetetraacetic acid). He also found that sodium chloride inactivated some forms while acetic acid had no effect on the multiple forms. All forms were inactivated after 1 min at 100°C.

Embs et al. (1965) showed that sulfite prevents browning caused by polyphenoloxidase by combining with the enzymatically produced o-quinone and stopping their condensation to quinones. Goodman (1957) and Hughes (1959) found that treatment with sodium bisulfite in combination with sodium chloride retards discoloration of fresh mushrooms; while Voinovitch et al. (1949) found that thiamine, or nicotinic acid, in combination with SO_2 was superior to SO_2 alone with respect to enzyme inactivation. On the other hand, Voinovitch (1951) reported that autoclaved mushroom juice turns brown upon exposure to air at room temperature due to non-enzymatic oxidation.

After the first "pinhead" mushrooms appear in the mushroom bed, the crop will follow a series of cycles. Batches of mushrooms appear in sudden outbreaks at intervals of about 10 days to two weeks. These outbreaks are called "flushes" or "breaks" and are followed by periods with only a few mushrooms appearing on the bed. A mushroom crop will consist of four or five breaks during a 2 to 3 month period. When the rate of production becomes uneconomical the mushroom beds are cleaned out and prepared for a new crop. Hughes et al. (1959) showed that the changes in amino acid composition with respect to successive breaks is consistent with the hypothesis that browning of mushrooms is due to the action of tyrosinase on tyrosine.

The present work was undertaken (1) to study the effects of different processing variables, and several of the chemical treatments reported in the literature, on product quality, and (2) to find a process which would yield a bacteriologically clean product with acceptable color and a flavor closely resembling that of fresh cultivated mushrooms.

EXPERIMENTAL

Drying procedure. Two varieties of cultivated mushrooms were studied: white and cream. They were purchased already trimmed either from local retail stores or from growers in Kennett Square, Pennsylvania. Unless otherwise stated, all experiments were carried out by washing the mushrooms by hand with tap water, slicing or dicing them in an Urschel Model RA cutter, and drying the pieces either in a through-circulation hot-air drier described by Sinnamon et al. (1968) or an air-convection batch tray drier built by the National Drying Machinery Company. In most of the experiments, washed mushrooms were dipped in aqueous chlorine solutions before cutting to reduce the bacteria count. To inhibit discoloration during the drying stage, cut mushrooms were treated with sulfite and other chemicals. The drying temperature was varied to determined the effect of this variable on color, bacteria count, and flavor of the dry product. The air velocities ranged from 200 to 250 ft/min.

Factors affecting bacteria count and color. The effect of the following factors on the color of the dry product was studied: (a) blanching in flowing steam and boiling water for 10 min; (b) mushroom variety; (c) break number; (d) dry-bulb temperatures in the range from 85° to 195°F, and a constant dew point of 65°F;

and (e) product moistures in the range from 4% to 13%. Also, several chemicals were examined for ability to inhibit discoloration by dipping cut mushrooms for 5 to 10 min in aqueous solutions of (a) 1% table salt, (b) 1% citric acid, (c) 1% ascorbic acid, (d) .5% EDTA (disodium ethylediamine-tetraacetate), (e) 0.5% EDTA plus 0.5% citric acid, (f) .05% cystein HCl, (g) 0.05% sodium bisulfite plus 0.5% EDTA, (h) 0.01% to 3.25% sodium bisulfite, (i) 2.5% sodium acid pyrophosphate (j) 2.5% sodium acid pyrophosphate plus 0.05% sodium bisulfite, (k) 1% thiamine plus 0.05% sodium bisulfite.

Fresh mushrooms of good quality have over one million bacteria/g. To reduce the bacterial population, whole mushrooms were dipped in solutions containing up to 800 ppm free chlorine. Dip solution temperatures of 70°F and 90°F were used. The treatment times ranged from 5 to 10 min.

Effect of processing variables on flavor. The products were tested by 3 to 4 tasters who were familiar with the work. Taste tests were preliminary and served to pick out the most important variables affecting flavor and texture. They were conducted informally and the findings were openly discussed.

To evaluate the texture, along with the flavor, the pieces were reconstituted for 5 min in boiling water and then sautéed in butter for approximately 4 min. When flavor was the more important variable studied, the samples were finely ground in a Wiley mill through a 20-mesh screen and tasted in a soup mix which was prepared by the following procedure:

1. Add 21 g mushroom powder and ¾ teaspoon salt to 250 cc water and bring to a boil.
2. Make a slurry of 3 tablespoons of starch and ½ cup of whole milk and add to the mushroom mixture.
3. Add the rest of the milk (2½ cups) and heat stirring constantly until thickened.

Effect of drying temperature on initial flavor. Since the literature emphasizes the importance of drying temperature on flavor, the effect of this variable was investigated by a taste panel of 67 trained judges. Dice, ⅜ in. × ⅜ in. × ⅜ in., were dried to approximately 10% moisture content at 90°, 140°, 170° and 195°F dry-bulb temperature, a constant dew point of 65°F, and an air velocity of 200 ft./min. The dew point was kept low to help maintain low piece temperature

Table 1. Effect of drying temperature and chlorine treatment on bacteria.

Experiment number[1]	Chemical treatment[2]			Dry bulb temp. of air during drying, °F (time)[3]		Bacteria colonies/g
	Concentration and chemical	Dip time min	Temp. of solution °F	First stage	Second stage	
85-2	—	—	—	90 (19 hr)	—	560,000
-3	—	—	—	140 (4.2 hr)	—	860,000
-5	—	—	—	170 (1.7 hr)	—	48,000
-4	—	—	—	195 (1.3 hr)	—	14,500
105-4A	—	5	75	140 (2.5 hr)	—	152,000
-1A	200 ppm Cl_2	5	75	140 (3 hr)	—	300,000
-2A	400 ppm Cl_2	5	75	140 (2.5 hr)	—	148,000
-3A	800 ppm Cl_2	5	75	140 (2.5 hr)	—	120,000
124	400 ppm Cl_2	5	75			
	300 ppm SO_2	10	75	110 (4 hr)	170 (1 hr)	6,900
122	400 ppm Cl_2	5	75			
	300 ppm SO_2	10	75	110 (3 hr)	175 (1 hr)	15,000
110-III-1	—	—	—	180 (3.15 hr)	—	73,000
III-6	800 ppm Cl_2	10	90			
	1200 ppm SO_2	5	75	180 (3.15 hr)	—	6,000
117-1	800 ppm Cl_2	10	90			
	200 ppm SO_2	5	75	110 (1 hr)	185 (2 hr)	7,200
-2	800 ppm Cl_2	10	90			
	200 ppm SO_2	5	75	85 (1 hr)	185 (2 hr)	5,200
-3	200 ppm SO_2	5	75	85 (1 hr)	185 (2 hr)	40,000

[1] In experiments 85-2 to 85-4, dice 3/8″ × 3/8″ × 3/16″ were dried. One-eighth in. thick slices were dried in the other runs.

[2] Whole mushrooms were dipped in aqueous solutions of chlorine. Sulfite treatment was carried out after cutting.

[3] Moisture content of final products was 9–10% in experiment number 85. In the remaining runs it ranged between 3.5% and 6.5%.

and thus prevent flavor and color changes. The mushrooms dried were of the cream variety. The products were prepared using the soup mix recipe above. The panel members were asked to rank the four samples in the order of preference.

Effects of drying temperature and product moisture on flavor during storage. Mushroom dice, ⅜ in. × ⅜ in. × 3/16 in., were dried to approximately 6½% and 12% moisture content at each of the following dry-bulb temperatures: 110°, 140° and 195°F. Samples of these products were packed in air in hermetically sealed cans and stored at 73°F. They were then tasted at approximately 2-month intervals by a panel of 21 judges who were asked to score each sample on a 5-point scale which is described by Kramer et al. (1962) and ranges from "definitely off-flavor, not acceptable" to "better than standard flavor."

A sample prepared from dry mushrooms which were freshly dried at 110°F to 10% moisture content was used as a standard. For statistical analysis, numerical values were then assigned to the different categories: the category "definitely off-flavor, not acceptable," received a score of 1; while a score of 4 was assigned to the category "equal to standard in flavor," and a score of 5 to the category "better than standard in flavor."

Comparison with commercial products. A product obtained from white variety mushrooms by drying dice ⅜ in. × ⅜ in. × 3/16 in. at 90°F dry-bulb temperature and 65°F dew point to 7% moisture content was compared in a white gravy mix to imported dry cultivated mushrooms and domestic freeze-dried mushrooms by a private food company.

Another sample was compared by a consulting firm (Hogan Associates, 1968) to freeze-dried *Agaricus bisporus* and to air-dried *Agaricus bisporus* from Germany and Formosa in three popular mushroom dishes: tuna fish cream of mushroom casserole, brown mushroom gravy, and cream of mushroom soup. The samples were produced by drying 3/16 in. slices of white variety mushrooms from the first break to 5% moisture content. Dehydration was carried out in two stages, first at 100°F dry bulb-temperature for 4 hr and then at 170°F dry-bulb temperature for 1 hr. The dew point was kept constant at 65°F and the air velocity was 200 ft./min.

Chemical analyses and color measurement. Moisture analyses were performed by dehydrating 10 g samples under vacuum for 6 to 7 hr at 84°C. The method of Nury et al. (1959) was employed for sulfite determination. An automatic Gardner Color Difference Meter (Model AC-2A, 200 series, H. A. Gardner Laboratory, Incorporated) was used to determine the Rd, a, and b tristimulus values. The Rd value is a measure of the percentage of light reflected by the sample relative to that reflected by a magnesium oxide standard. Positive a values indicate redness and negative values greenness. Positive b

Table 2. Effect of mushroom variety, drying temperature, sulfite treatment, blanching, and chlorine treatment on color.

Experiment number	Mushroom variety	Sizes of pieces	Pretreatment[1] ppm Cl_2	Pretreatment[1] ppm SO_2	Drying temp., °F (time) First stage	Drying temp., °F (time) Second stage	Color[2,4] Rd	Color[2,4] a	Color[2,4] b
87-6	Cream	3/8″ × 3/8″ × 3/16″	—	—	110 (6.5 hr)	—	29.1	+5.7	+12.0
87-5	Cream	3/8″ × 3/8″ × 3/16″	—	—	140 (3.0 hr)	—	27.0	+4.9	+11.1
87-2	Cream	3/8″ × 3/8″ × 3/16″	—	—	195 (1.5 hr)	—	23.8	+2.4	+13.6
	Chilean (Boletus luteus)	—	—	—	—	—	12.1	+4.0	+14.4
	European (Boletus edulis)	—	—	—	—	—	27.5	+0.4	+17.9
46	White	3/8″ × 3/8″ × 3/16″	Blanched[3]		140 (3.3 hr)	—	23.1	+0.7	+13.1
88-1	White	3/8″ × 3/8″ × 3/16″	—	—	80 (50 min)	115 (5 hr)	39.8	+3.1	+13.1
88-2	White	3/8″ × 3/8″ × 3/16″	—	—	80 (50 min)	140 (3.2 hr)	38.9	+3.1	+13.5
88-3	White	3/8″ × 3/8″ × 3/16″	—	—	80 (50 min)	200 (1.2 hr)	32.3	+2.4	+13.0
104-1	White	1/8″ thick slices	—	—	140 (3.3 hr)	—	44.4	+0.9	+11.7
104-3	White	1/8″ thick slices	—	—	80 (1.5 hr)	150 (2 hr)	46.5	+2.2	+11.8
104-4	White	1/8″ thick slices	—	250	80 (1.5 hr)	150 (2 hr)	50.1	+1.5	+13.8
108-E1	White	1/8″ thick slices	—	—	180 (2.5 hr)	—	24.4	+0.6	+12.6
108-E2	White	1/8″ thick slices	—	1200	180 (2.5 hr)	—	41.7	+0.5	+20.0
108-F1	White	1/8″ thick slices	—	—	80 (1.5 hr)	180 (1.3 hr)	38.9	+0.9	+12.7
108-F2	White	1/8″ thick slices	—	600	80 (1.5 hr)	180 (1.3 hr)	41.5	+0.9	+14.8
108-F3	White	1/8″ thick slices	—	300	80 1.5 hr)	180 (1.3 hr)	41.3	+0.3	+14.4
124	White	1/8″ thick slices	400	300	110 (4 hr)	170 (1.0 hr)	49.4	+1.1	+14.2
121-2	White	1/8″ thick slices	400	300	110 (3 hr)	175 (1.3 hr)	43.1	+1.1	+14.0

[1] Whole mushrooms were dipped in the aqueous Cl_2 solution. Sulfiting was carried out after cutting. Both solutions were at room temperature. Treatment times ranged from 5 to 10 min.
[2] Moisture content of all products below 7.5%.
[3] For 10 min with live steam.
[4] Rd values describe whiteness of product. Positive a and b values indicate redness and yellowness, respectively.

values indicate yellowness and negative blueness. The meter was standardized with a Gardner Ceramic Standard CLY0032 (Rd = 60.8, a = −1.8, b = +22.7).

RESULTS AND DISCUSSION

Bacteria. The effects of drying temperature and chlorine water treatment on bacteria are shown in Table 1. At 140°F, which is recommended in the literature for blanched mushrooms, a satisfactory reduction in bacteria was not achieved when unblanched mushrooms were dried to about 10% moisture content (see experiment number 85-3). Even when whole mushrooms were dipped for 10 min in aqueous solutions containing up to 800 ppm free chlorine before they were cut and dried at 140°F to between 3.5% to 6.5% moisture content, the bacterial contamination remained too high. This can be readily seen from experiments 105-1A to 105-4A.

Satisfactory reduction in total bacteria count was obtained when mushrooms were treated for 10 min with a solution containing approximately 400 ppm free chlorine prior to drying at 170°F or 175°F dry-bulb temperature. Low bacteria counts were obtained even when drying at these temperatures was limited to a short time at the end, most of the drying having been accomplished at 110°F dry-bulb temperature (experiments 122 and 124).

Apparently, most bacteria are killed at the end of the drying process when the temperature of the mushroom pieces approaches the dry-bulb temperature of the air. At 180°F and at 185°F a fair reduction in bacteria count was observed when chlorine treatment was omitted (see experiments 110 and 117). With chlorine treatment the bacteria count of the product was even lower at these drying temperatures. As can be seen from experiment 85-4, dehydration at 195°F dry-bulb temperature yields a very clean product bacteriologically without pretreatment.

Color. The effects of blanching, sulfiting and chlorine treatment on the color of air-dried mushrooms can be seen from Table 2, which lists some typical Gardner Color Difference Meter readings of products dried at different dry-bulb temperatures. For comparison, the color readings of two of the more important imported dry mushrooms are included. Dry mushrooms of cream variety were much darker than white mushrooms at all drying temperatures. This can be seen from the Rd values which correlated very well with visual observations of lightness. Cream variety mushrooms yielded products which were lighter than the imported dry Chilean *Boletus luteus* and similar in color to the European *Boletus edulis*.

For both mushroom varieties, discoloration was proportional to the amount of heat treatment, and lower drying temperatures yielded lighter products even if low temperature drying was limited to the first stage of a two-stage drying process. Blanching for 10 min caused excessive darkening during drying (experiment 46). The color varied somewhat from batch to batch because the raw materials were non-uniform in quality: they represented different break numbers, they were obtained from different sources of supply, and they were grown and stored under different conditions.

Visual inspection revealed that pretreatment of mushroom pieces with citric acid, table salt, ascorbic acid, EDTA, or sodium acid pyrophosphate had little effect on color of dried mushrooms. Of the chemicals tested, only sodium bisulfite was found to decrease mushroom discoloration during drying.

Under the same drying conditions lighter products were obtained with sulfite-treated mushrooms. A bright yellow color, which was visually observed in all sulfited dry mushrooms, became very apparent to the naked eye if the sulfite concentrations in the dry product were over 100 ppm. This was true of mushrooms which needed SO_2 treatment most, i.e., soft mushrooms which discolored readily on cutting and those obtained from later breaks. Although this yellow color was more noticeable on the surface, color measurements on powders from sulfite-treated, dry mushrooms showed measurable increases in the b values (see e.g. experiment 108).

Chlorine treatment resulted in addi-

Table 3. Effect of break number on color.

Experiment number	Break number	Mushroom variety	Size of pieces	Pretreatment[1] ppm Cl_2	ppm SO_2	Drying temp., °F (time) First stage	Second stage	Color[2] Rd	a	b
124	1	White	3/8″ × 3/8″ × 3/16″	400	300	110 (4 hr)	170 (1.5 hr)	49.4	+1.1	+14.0
123	2 & 3	White	3/8″ × 3/8″ × 3/16″	400	300	110 (4 hr)	172 (1.5 hr)	44.1	+0.7	+16.0
122	5	White	3/8″ × 3/8″ × 3/16″	400	300	110 (3 hr)	172 (1.5 hr)	38.9	+1.4	+16.4

[1] Whole mushrooms were dipped in the aqueous Cl_2 solution. Sulfiting was carried out after cutting. Both solutions were at room temperature. Treatment times ranged from 5 to 10 min.
[2] Moisture content of all products below 7.5%.

Table 4. Mean ranking scores[1] of products dried at different temperatures.

Product dried at	Mean rank
90°F	2.48
140°F	2.46
170°F	2.46
195°F	2.60

[1] Samples were ranked in the order of preference by 67 judges.

Table 5. Analysis of variance of taste panel scores[1] of products dried at different temperatures.

Source	Degrees of freedom	Sum of squares	Variance of mean square	F-values Calc.	Tab. (5%)
Whole table	267	2010	7.52		
Between samples	3	0.85	0.283	.037	2.65
Residual error	264	2009.15	7.61		

[1] Mean ranking scores and drying temperatures are given in Table 4.

tional darkening. However, dipping of whole mushrooms for about 10 min in warm aqueous solutions (75°F to 90°F) containing approximately 400 ppm free chlorine, followed by sulfite treatment and dehydration in two stages, yielded light products which were bacteriologically clean (see experiments 121 and 124).

The effect of break number on color is shown in Table 3. Inspection showed mushroom discoloration increased drastically with successive breaks. The first break yielded a nice light tan color at low drying temperatures without sulfite treatment, and at higher temperatures with sulfite treatment. Mushrooms from the fifth break yielded darker products at all drying temperatures; even low-temperature drying combined with sulfite pretreatment gave only a fair colored product. If it is assumed that browning during drying results from the action of tyrosinase on tyrosine, these results are in agreement with the analytical findings of Maggioni et al. (1968), who found that the tyrosine content of fresh mushrooms increases from the first to the fourth break. This contradicts Hughes et al. (1959) who found the opposite to be true.

All color measurements reported in this publication were made on mushrooms dried to moisture contents of 7½% or lower. Products containing more than 10% moisture turned brown within a short time. At moisture contents lower than 7.5% the color was quite stable when the products were hermetically sealed in tin cans.

Initial flavor. Preliminary tasting of products by four judges revealed that mushrooms dried to 2% moisture content were tougher on reconstitution than those dried to only 7% moisture content. The over-dried products also had a somewhat burnt or bitter flavor if they were dried at elevated temperatures (180°F or higher). It was also observed that dehydrated products containing more than 100 ppm sulfite had an off-flavor.

A larger taste panel was used to study the effect of drying temperature on flavor, since preliminary tasting by four judges yielded inconclusive results. Table 4 summarizes the mean rank scores of 67 judges obtained on products dehydrated at 90°, 140°, 175° and 195°F to 10% moisture content. In this table numerical values from 1 to 4 were assigned to the responses, the preferred samples receiving a lower score.

Table 5 gives the analysis of variance for the sample means. Since the calculated variance ratio F was lower than the tabular value corresponding to a 5% level of significance, it was concluded that the sample means are statistically the same and that drying temperatures up to 195°F may be used without adversely affecting flavor if drying is carried out to 10% moisture content.

Shelf life of products. Table 6 lists the mean flavor scores obtained by 21 tasters after 0, 2, 5, and 7 months of storage for mushroom products dried to 6½ and 12% moisture at each of the following dry-bulb temperatures: 110°, 140° and 200°F. In this table products considered equal to a freshly dried standard were given a score of 4, inferior ones were rated on a scale ranging from 1 to 3, and those judged better than the standard received a score of 5. The numerical results were analyzed by analysis of

Table 6. Comparison of mean scores[1] after various storage times.[2]

Processing data	0 Months Mean score	Duncan's test 0.05 level	2 Months Mean score	Duncan's test 0.05 level	4 Months Mean score	Duncan's test 0.05 level	7 Months[3] Mean score	Duncan's test 0.05 level
110°F, 6.5% Moist.	3.45	A	3.78	A	3.65	A	3.65	A
140°F, 6.5% Moist.	3.50	A	3.96	A	3.75	A	3.48	A
195°F, 6.5% Moist.	3.45	A	3.57	AB	3.55	A	3.26	A
110°F, 12% Moist.	3.95	A	3.17	BC	2.75	B	2.91	B
140°F, 12% Moist.	3.75	A	2.96	CD	3.40	A	2.74	B
195°F, 12% Moist.	3.35	A	2.52	D	2.70	B	2.61	B

[1] Range of Scores: 5 "better than freshly dried standard," 4 "same as standard," to 1 "definitely off-flavor."
[2] 21 judges in taste panel.
[3] The mean flavor scores which were not significantly different have been assigned the same letter (Duncan, 1955) in this column.

variance. For each storage period, F tests showed the difference among the mean flavor scores to be significant at the 0.05 level.

A mean comparison was made using the multiple range test proposed by Duncan (1955). The mean flavor scores which were statistically equal have been assigned the same letter in the corresponding last column of Table 6. After 2, 4, and 7 months of storage at room temperature the samples containing 6.5% moisture were equal to the freshly prepared standard; and the products which contained 12% moisture were judged inferior to the standard sample.

Quality comparison. Taste tests conducted by two commercial companies, one of which is a large-scale user of dry mushrooms, showed unblanched air-dried mushrooms to be superior to other imported air-dried mushroom products: they had a better flavor, color and texture than the dry *Boletus luteus* imported from Chile as well as the dry *Agaricus bisporus* imported from Germany and Formosa. Unblanched air-dried mushrooms also were found to be equal in flavor but inferior in texture to freeze-dried mushrooms. However, it was pointed out that the crisper texture is a desirable attribute in some applications.

CONCLUSION

Blanched mushrooms darken when they are exposed to hot air during drying. Products with good flavor and storage stability, and a better color and shape, were obtained by dehydrating mushrooms unblanched.

The most important processing variables affecting color during drying of unblanched mushrooms are mushroom quality, variety and break number. To obtain light colored products the raw material should be firm, of the white variety, and from an early break. Prior to drying certain precautions should be taken to minimize browning. The mushroom should be stored under refrigeration and cut in a machine that imparts very little compressing or shearing. Also, the wash water and chemical dipping solutions should be kept at or below about 90°F.

No chemical treatment could be found which would inhibit discoloration completely. Nor did chlorine water treatment alone sufficiently reduce the microorganisms normally present in mushrooms. However, by combining low temperature drying at about 100 to 110°F in the first stage with high temperature drying (170° to 180°F) in the second, finishing stage, products were obtained which were both light in color and relatively low in organisms.

The moisture content of the product should be between 4% and 8%. Mushrooms dried to very low moisture contents (below 4%) are tough on reconstitution and poor in flavor especcially if they were dried at higher drying temperatures. The dry products should be packed in air-tight containers and must not be permitted to increase in moisture content since color and flavor changes occur readily during storage at moisture contents higher than 10%. Also, the sulfite content in the product should be below 100 ppm. Higher concentrations cause an after taste objectionable to some people.

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